Lights Out Operations of a Multi-Asset Air, Ground, Space Sensorweb

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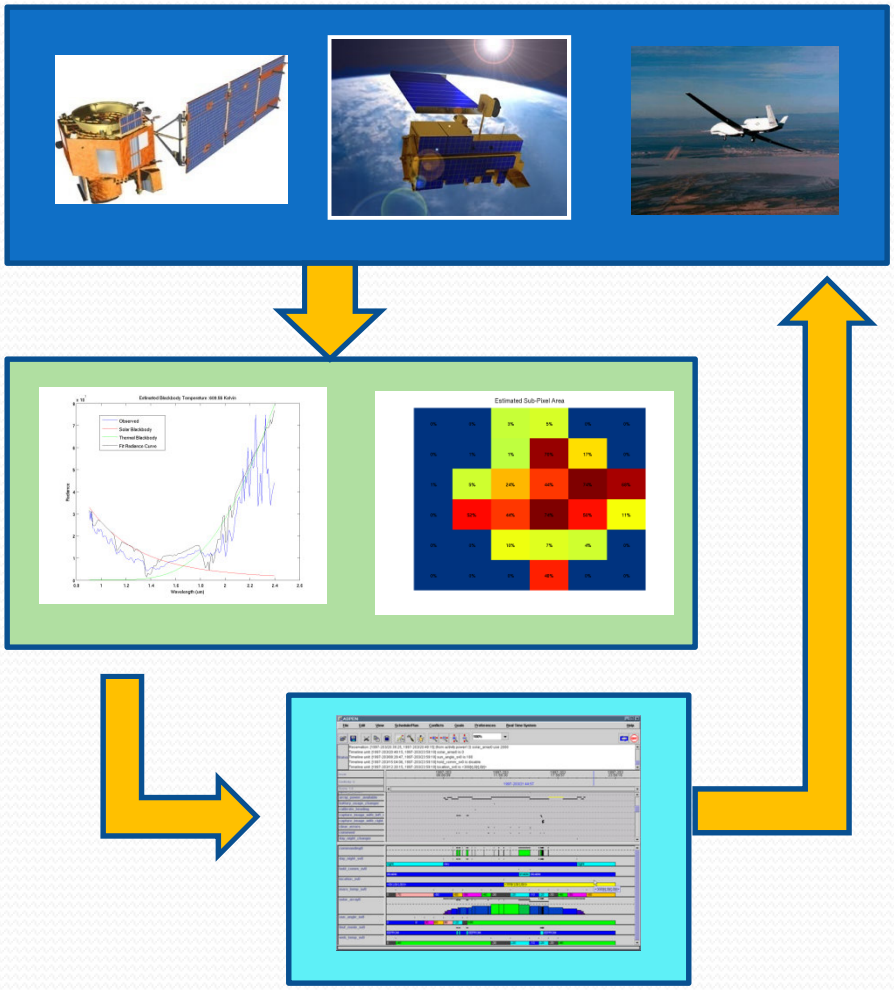
Sensorweb Concept

- Data sources
- Processing
- Tasking



Examples

- Directing a pointable satellite to track volcanic activity as measured by ground sensors.
- Directing a subsurface submersible to investigate a possible eddy event as detected by surface radar.
- Noting the signature of earthquakes from seismographic and GPS sensors and allocating a higher data rate of acquisition from those best placed to measure the areas likely to have future activity.

OGC Services - Overview

- Enable generic web access to sensors
- To
  - task to acquire new data
  - acquire archived data,
  - subscribe to alerts, and
  - process data.

Sensor Planning Services

- used to:
  - determine if a sensor is available to acquire requested data.
- For example, using the SPS, an observation request to a space asset can be issued to
  - acquire science data,
  - determine the status of an existing request and
  - cancel a previous request.

Sensor Observation Service

- Used to retrieve engineering or science data. This includes:
  - access to historical data as well as
  - data requested and acquired from the SPS.

The Web Processing Service (WPS)

- Used to perform a calculation on the acquired sensing data
- This includes processing the raw data into derivative products such as:
  - vegetation indices,
  - soil moisture,
  - burn areas,
  - lava flows,
  - flood coverage areas
  - effusions rates,
  - etc.

Sensor Alert Service

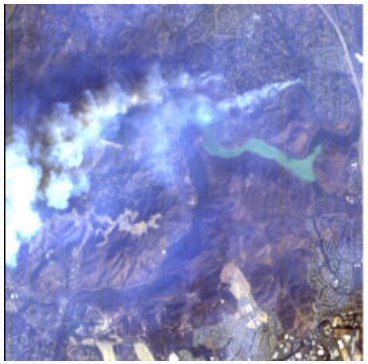
- used to publish and subscribe to alerts from space, ground, and air assets.
- Users register with this service and provide conditions for alerts.
- When these conditions are met by the acquired data, alerts containing the data along with time and location of the event are automatically issued to the user.

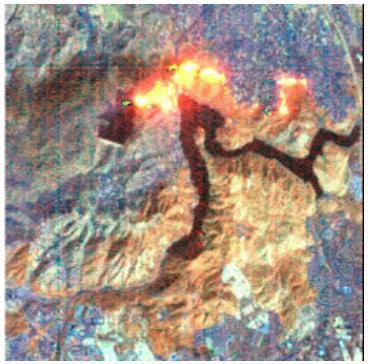
SensorML

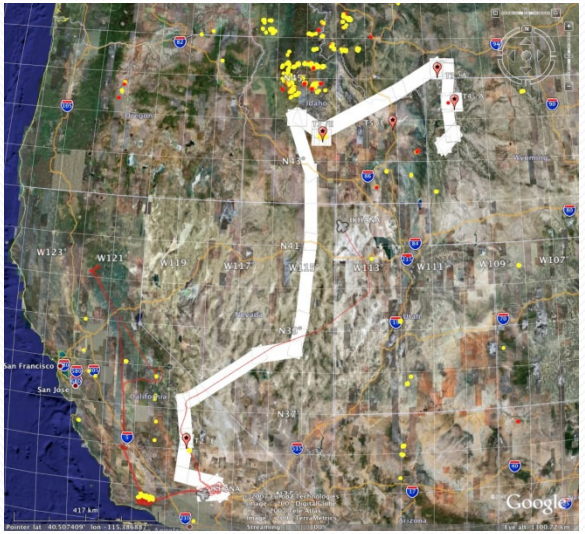
- Used to provide a description of the space, air, and ground instruments and their associated products and services
- SensorML provides a high level description of sensors and observation processes using an XML schema methodology.
- It also provides the functionality for users to discover instruments on the web along with services to task and acquire sensor data (such as the SPS, SOS, SAS, and WPS).

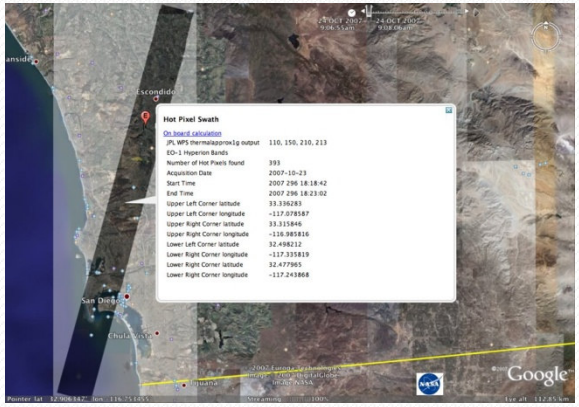
EO-1 and Ikhana (UAS/ARC, GSFC)

- EO-1 imagery of the Witch Fire – 23 October 2007
- UAS Flight Path (on Sumer 2007 flight)
- Geobliki Mashup of JPL thermal product









Kilauea Deployment (Davies/JPL)

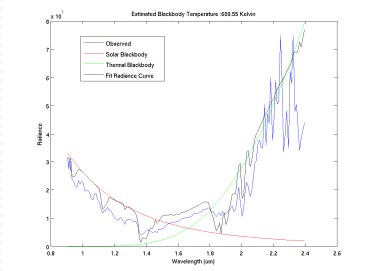
- Recently deployed SO2 sensors to Pu'uoa vent (HVO) (sensors built by Behar/JPL)
- Sensors integrated into volcano monitoring suite (Davies)
- OGC compliant services under development (AIG)

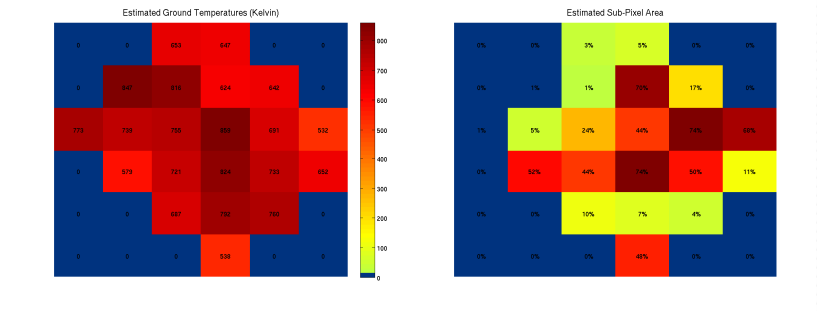
Mount Erebus Collaboration (Davies/JPL, Kyle/NMT)

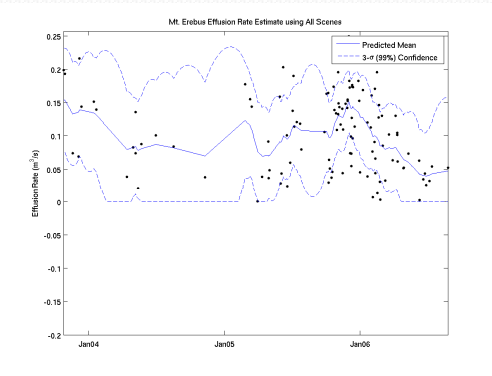
- Linkup with in-situ sensors (Mt. Erebus Volcano Observatory/ NMT/Kyle)
- OGC Services under development
  - Sensor Alert Service, Sensor Observation Service

Mt. Erebus – Automated processing

- On-demand modeling of
  - Thermal output → sub-pixel lava coverage → effusion rate
  - Implemented via Web Processing Services (WPS)



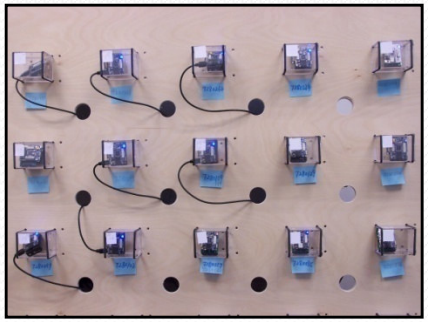




CVO/WSU/MSH Collaboration

- Deploying Sensors to Mount Saint Helens
- Linkage with ground-space sensorweb

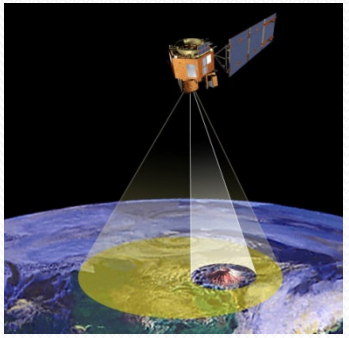
OASIS – CVO/WSU/MSH (Song/WSU PI)



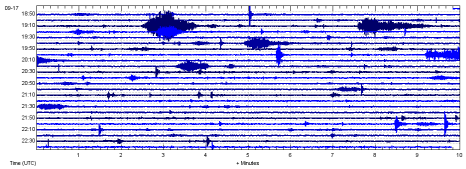
Node SW Dev (WSU lead)

Hardware Nodes (operations) USGS lead

Space Segment Event Detection Control Center (JPL Lead)



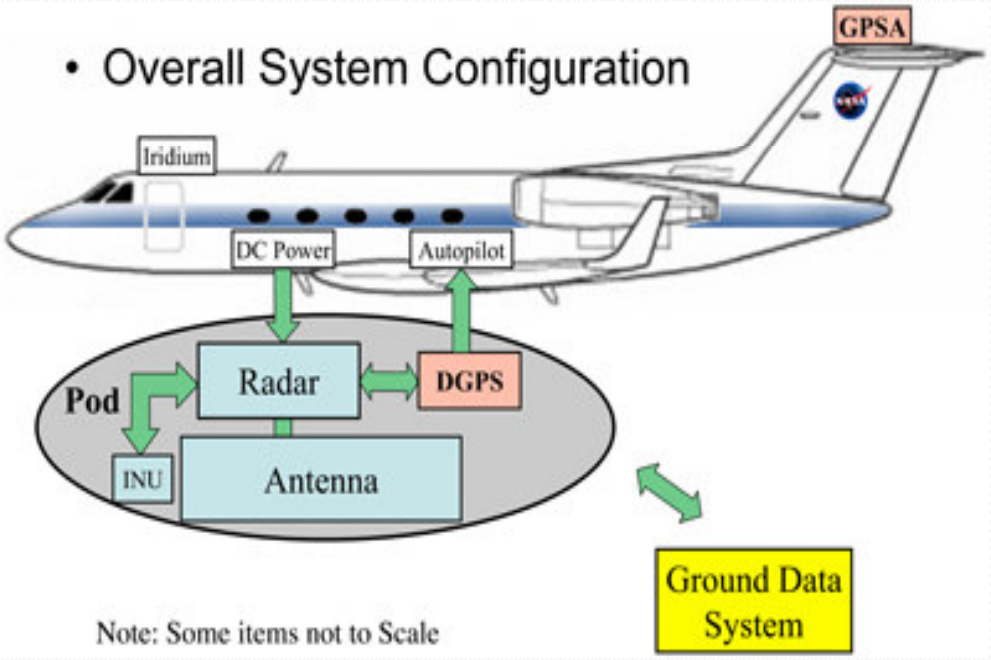
Comm link to WSU/CVO



JPL Plans

- Control Center and event detection frameworks applicable to wide range of domains (Undersea)
- JPL/GSFC/Vightel to provide EO-1 SPS 1.0 as Open Source
- JPL to also provide SPS, SOS, SAS for MSH CVO sensors

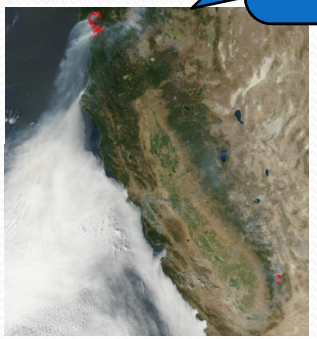
Unpiloted Aerial Vehicle Synthetic Aperture Radar Collaboration (Y. Lou / JPL PI)



Courtesy: http://uavsar.jpl.nasa.gov

Fire is spotted…

Fire Sensor Web Scenario (1 of 7)



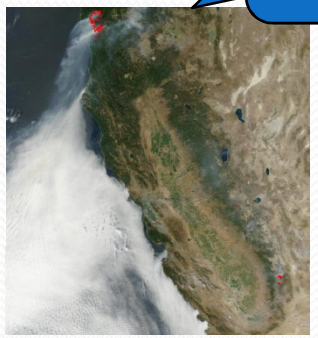
Fire is initially, roughly located by MODIS/Rapidfire

Fire observer reports fire

Fire Sensor Web Scenario (

UAV sent initial coordinates of fire location

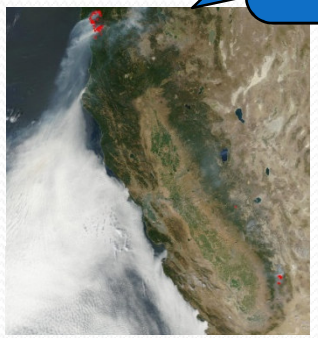
Fire is initially, roughly located by MODIS/Rapidfire



Fire observer reports fire

Fire Sensor Web Scenario (Cont'd)

Fire is initially, roughly located by MODIS/rapidfire



UAV responds to fire alert

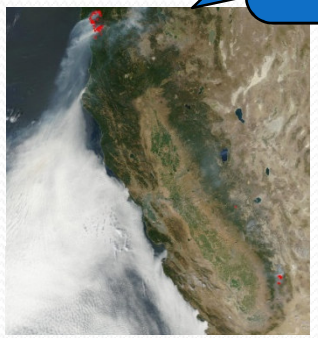
UAVSAR generates flight plan to cover the alerted fire area and executes plan

Fire observer reports fire

Fire Sensor Web Scenario (...)

UAV collects and processes fire data

Fire is initially, roughly located by MODIS/rapidfire



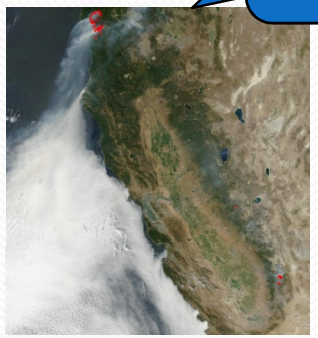
UAVSAR generates flight plan to cover the alerted fire area and executes plan

fuel loading map

used with wind, elevation information to predict likely fire progression

Fire observer reports fire

Fire Sensor Web Scenario (cont.)



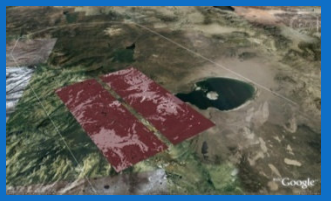
Fire is initially, roughly located by MODIS/rapidfire

Fire observer reports fire

UAV tracks fire progression

UAVSAR generates flight plan to cover the alerted fire area and executes plan

fuel loading map



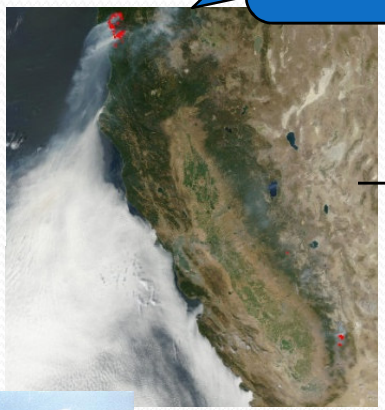
used with wind, elevation information to predict likely fire progression

UAVSAR autonomously alters flight plan to track fire progression – providing precise fire progression data

Fire Sensor Web Scenario (Concept)

UAV calls in other space assets

Fire is initially, roughly located by MODIS/rapidfire

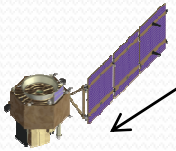


UAVSAR generates flight plan to cover the alerted fire area and executes plan

fuel loading map

used with wind, elevation information to predict likely fire progression

Fire observer reports fire

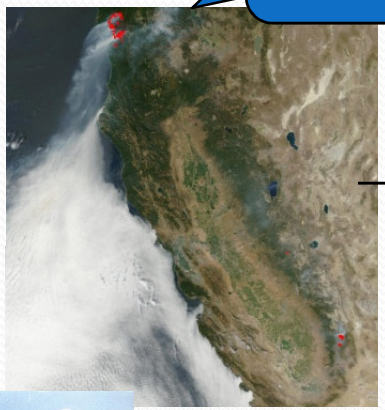


Precise fire location enables autonomous response of other assets (e.g. EO-1) to also acquire fire data

UAVSAR autonomously alters flight plan to track fire progression – providing precise fire progression data

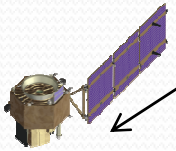
Fire Sensor Web Scenario (Version 1)

Fire is initially, roughly located by MODIS/rapidfire



Fire observer reports fire

Precise fire location enables autonomous response of other assets (e.g. EO-1) to also acquire fire data



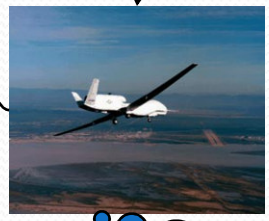
UAV continues to re-plan and track fire

Flight continues until alerts or resources are exhausted.

UAVSAR generates flight plan to cover the alerted fire area and executes plan

fuel loading map

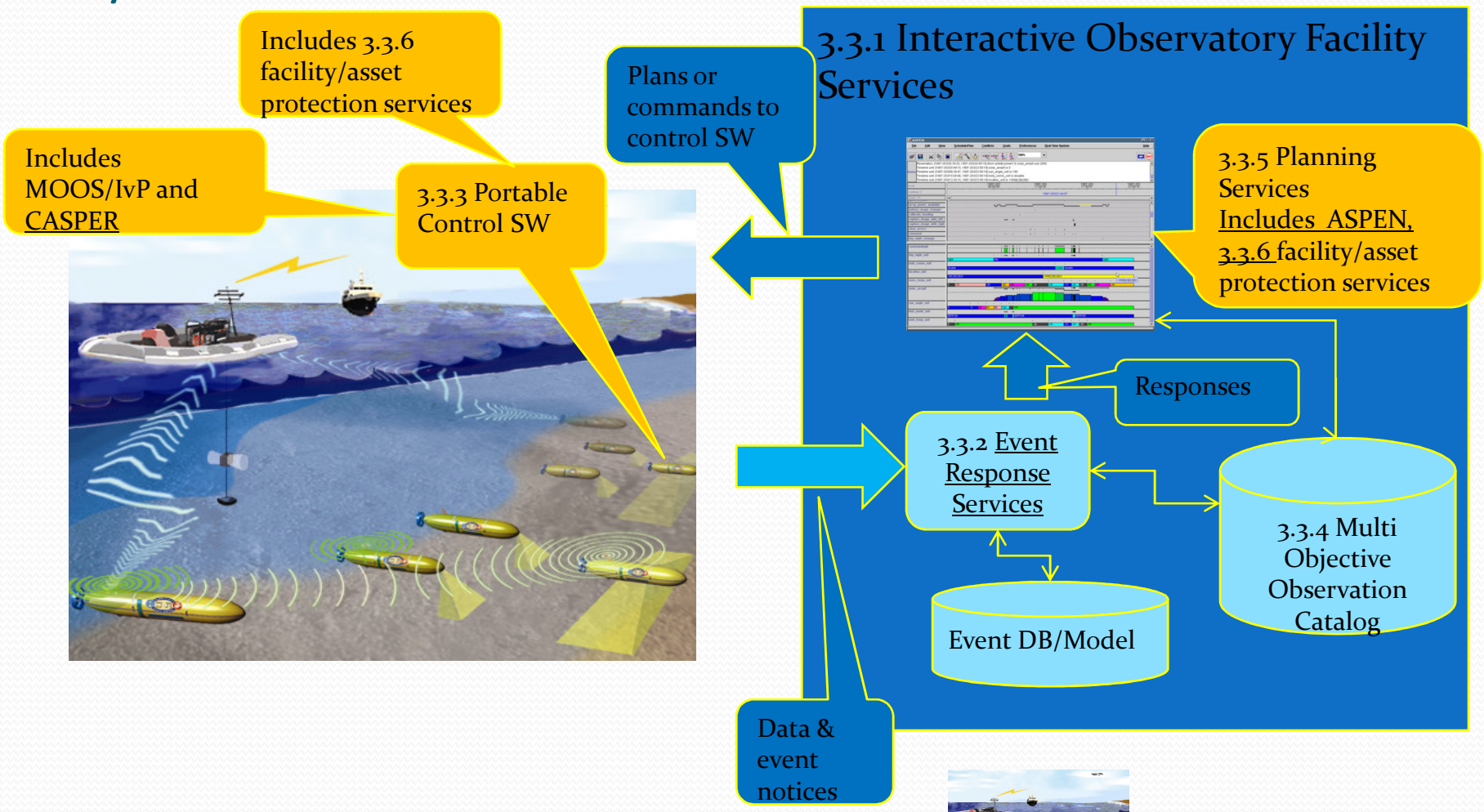
used with wind, elevation information to predict likely fire progression



UAVSAR autonomously alters flight plan to track fire progression – providing precise fire progression data

Undersea - Planning & Prosecution

NSF/ORION



Related Work

- Many NASA AIST efforts (sensorwebs)
- Multi-rover coordination (MISUS/JPL, CMU, others)
- Multi-agent systems for space (Clement, Barrett et al.)
- Marine autonomous systems (Leonard/Princeton, Henrik/MIT, MBARI, …)
- …

Conclusions

- Space assets are being networked with air, sea, and ground assets
- Coordination of assets automated through use of OGC Web services
- Enables multiple perspective science study
- Applicable across wide range of science disciplines: volcanology, flooding, wildfires, …
- Applicable across wide range of assets: space, air, marine, ground